A Summary of Current Program and
Preliminary Report of Progress

RESEARCH

on

NAVAL STORES and MAPLE SAP AND SIRUP PROCESSING AND PRODUCTS

and

REVEGETATION and WEED AND BRUSH CONTROL ON FOREST AND RELATED RANGES

of the Agricultural Research Service,
United States Department of Agriculture
and cooperating
State Agricultural Experiment Stations

This progress report of U.S.D.A. and cooperative research is primarily a tool for use of scientists and administrators in program coordination, development and evaluation; and for use of advisory committees in program review and development of recommendations for future research programs.

The summaries of progress on U.S.D.A. and cooperative research include some tentative results that have not been tested sufficiently to justify general release. Such findings, when adequately confirmed will be released promptly through established channels. Because of this, the report is not intended for publication and should not be referred to in literature citations. Copies are distributed only to members of Department staff, advisory committee members and others having an interest in the development of public agricultural research programs.

This report also includes a list of publications reporting results of U.S.D.A. and cooperative research issued during the past year. Current agricultural research findings are also published in the monthly U.S.D.A. publications, Agricultural Research, Agricultural Marketing, and The Farm Index.

UNITED STATES DEPARTMENT OF AGRICULTURE
Washington, D. C.
1963

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This progress report was compiled by David J. Ward, Executive Secretary, Forestry Research Advisory Committee, Office of Administrator, Agricultural Research Service, U. S. Department of Agriculture, Washington 25, D. C.

INTRODUCTION

This is ONE part of a TWO part report of cooperative U.S.D.A. research relating to forested land and related ranges.

This part of the Forestry report deals with research conducted by certain divisions in the Agricultural Research Service; the other and larger part includes discussions of all Forest Service research. No details of State station research are included in the report except as such work is cooperative with the U.S.D.A.

Agricultural Research Service (ARS) investigations with naval stores and maple sap and sirup deal with the development of new and improved products and processing technology and the acquisition of basic knowledge about chemical composition and chemical and physical properties of these products. During the past fiscal year, about 21 professional man-years were devoted to these areas of utilization research.

The portion of ARS range improvement research covered in this report deals with problems associated with revegetation and fertilization of forest ranges. Methods of seeding, establishing, and managing ranges for domestic livestock are studied together with evaluations of the suitability of grass species or varieties for use as range plants. ARS investigations in this area involved about 3 professional man-years in fiscal year 1963.

Research on the control of weeds and brush on forest and related grazing lands is a part of ARS weed control studies with forage and range plants. In fiscal year 1963 about 22 professional man-years were devoted to the area of work covered in this report.

The above estimates of scientific effort do not include any part of the research programs of a basic character that will produce results of value to many problem areas.

Successful applications of results of agricultural research have been numerous and impressive. A few examples from the research areas covered in this part of the report are presented here.

> Brush and Weed Control. Over four and one-third million acres of grazing land was sprayed for brush and weed control in 1959. Removal results in dramatic improvement on ranges having residual stands of forage species. For instance, in western Oklahoma, control of 88% of shinnery oak increased oven-dry forage production 1,700 pounds per acre; shinnery oak poisoning of cattle was eliminated. Sagebrush removal in western states, either mechanically or by spraying with 2,4-D, increases forage production two to three times. Control of brush and weeds also serves as land preparation for seeding potentially more productive forage species. Successful seedings of grasses are made in the ashes of chaparral if the chaparral sprouts are sprayed with 2,4-D and 2,4,5-T. Crested wheatgrass is successfully established on sagebrush land sprayed with 2,4-D.

Also, control of weeds by selective herbicides makes possible spring seeding of grasses and legumes where such plantings are desirable. Good yields of high quality forage is available in the seeding year. For example, in Mississippi, coastal bermuda grass sprigged in May and sprayed immediately with simazine at four pounds per acre yielded 7,500 pounds per acre of dry matter as compared with 3,800 pounds of bermuda grass and 3,200 pounds of weeds on the untreated check. Herbicides have demonstrated their usefulness for hastening desirable plant succession or altering the direction of successional trends so that increased grazing and land conservation can be accomplished.

Maple Sirup. A new and simple fermentation process has been developed by which "buddy" sirup can be reclaimed, making it a marketable product. "Buddy" sirup in 1963 caused a loss of 17% of the potential maple sirup crop and of hundreds of thousands of farm dollars. "Buddy" sirup, which has an unpalatable flavor, results when maple trees come out of dormancy, due to warm weather, usually late in or following the sap harvest season. When producing "buddy" sap, the trees often show visible swelling of the buds, hence the name. With the solution of minor technical problems, this new process (public service patent pending) will prevent a repetition of the 1963 major crop disaster, and will be used to reclaim the very late flows of sap that will now be normal with the use of the germicidal taphole pellet reported last year.

Maleopimaric Acid used in Photographic Process. Maleopimaric acid, an easy-to-make chemical produced directly from pine gum, is already in use in the photographic industry, and many other applications are being developed. The new acid is the first chemical produced directly from pine gum without first processing the pine gum into turpentine and rosin. More than 300 companies and private research organizations have favorably evaluated the new acid for use in such items as paper coatings, printing inks, and a variety of products requiring a plasticizer, emulsifier, or a resin. The current production is estimated at 240,000 pounds annually.

The production of maleopimaric acid is particularly suited to processors of naval gum stores. Pilot plant operations at the Naval Stores Laboratory show that it can fit into the normal production process for turpentine and rosin with little additional effort or equipment.

I. NAVAL STORES PROCESSING AND PRODUCTS
Southern Utilization Research and Development Division

Problem. More uses for turpentine, rosin and pine gum need to be developed through research to provide new industrial markets for current and anticipated production of gum naval stores. These gum naval stores products face serious competition for markets from research-developed products, especially those from the chemical and petroleum industries. As an illustration, turpentine has lost substantially all of its industrial solvent market to low-cost petroleum based solvents. New fundamental information about the chemistry, composition and properties of pine gum, rosin and turpentine is needed to fully exploit their unique characteristics in the production of new and improved industrial products having utility as industrial chemicals, polymers, plastics, elastomers, resins, plasticizers, surface coatings, textile finishes, odorants, insecticides and herbicides. There is also a serious need to improve existing processes and develop new processing technology for the industry.

USDA PROGRAM

The Department has a continuing long-term program at Olustee, Florida, involving organic chemists and a chemical engineer engaged in both basic and applied research to discover and develop new and improved uses for pine gum and its products. In basic research on the chemical composition and the properties of gum naval stores materials the emphasis is on the isolation and characterization of some of the unidentified components of pine gum, rosin, and derivatives to obtain information that will aid in the further industrial utilization of gum naval stores. The U. S. Forest Service cooperates by supplying selected samples of pine gum. Informal cooperation is maintained with industry. In research to develop new and improved industrial products from pine gum, rosin, turpentine, or their components, conversion of the resin acids derived from gum rosin and pine gum to new polyfunctional products by reaction with suitable chemicals is under investigation to develop intermediates for production of resins, plastics, plasticizers, and other products. Another research approach involves the condensation of the unsaturated (olefinic) materials present in pine gum with certain reactive chemicals (dienophiles) to produce industrially useful chemicals. Research is also being conducted to develop uses for photosensitized oxidized pine gum and components, primarily in the fields of plastics and rubber. Other research includes investigations to convert turpentine and rosin into polymerizable products suitable for making new polymers, plastics, and resin; to prepare chemical intermediates and modified rosin compositions by hypochlorite reaction of rosin and resin acids; to convert rosin, resin acids, and resin acid derivatives to polyfunctional compounds useful in plastics, resins, and surface coatings by formaldehyde addition and subsequent reactions; and to produce reactive chemical intermediates from turpentine by reaction with inexpensive low molecular weight compounds. The Pulp Chemicals Association supports a Fellowship at the Naval Stores Laboratory for the purpose of conducting research to develop a suitable method for determining rosin and rosin derivatives in protective coatings, a necessity if rosin is to be allowed in certain types of these coatings from which it is now excluded. Additional research is in progress under contract at the University of Cincinnati, Cincinnati, Ohio, on the application of the oxo and related reactions to terpenes and resin acids to produce new, useful alcohols, aldehydes, and/or acids, and the characterization of the products thus obtained.

Contract research at Cornell University on the synthesis of terpene alcohols and glycols for use in the production of new and useful terpene derived polymers is being initiated.

The Federal in-house scientific research effort in this area totals 15 professional man-years. Of this total 13.7 is devoted to new and improved industrial products and 1.3 to new and improved processing technology. The contract research involves an additional 1.5 man-years on new and improved industrial products.

The following lines of work were terminated during the year: (1) The isolation and characterization of some of the major unidentified components in pine gum, rosin and some of their derivatives (under chemical composition and physical properties), and (2) the photochemical addition of suitable reagents to resin acids of pine gum origin to produce new chemicals of potential utility in the fields of surface active agents, textiles, paper and plastics (under new and improved industrial products).

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Composition and Physical Properties of Pine Gum. Research is in progress to isolate and characterize some of the unidentified components of pine gum and its derivatives to provide basic information that will aid in the further industrial utilization of gum naval stores products.

The new resin acid recently isolated from slash pine gum has been termed elliotinoic acid. Upon reduction of this acid, the previously isolated elliotinol is produced. Elliotinoic acid is the first bicyclic diterpene acid to be isolated from the oleoresin of the pine. It is not present in any detectable quantities in longleaf oleoresin nor in wood rosin. The ultraviolet and infrared spectra of the new acid indicates that it has two conjugated double bonds and at least one exocyclic methylene group. The acid forms a crystalline methyl ester and sodium salt. Indications are that the methyl ester has a double bond arrangement similar to that proposed for a closely related acid isolated by other workers from the bark of the common juniper. Dehydrogenation of the methyl ester gave a compound with ultraviolet absorption characteristic of a trisubstituted naphthalene (S5 2-36).

The project under which this work was conducted has been discontinued and the personnel transferred to a project on development of polyester resins from pine gum derivatives. Since some of the components separated during the course of the research have considerable influence on polyester resins obtained from pine gum, further work will be done on some of these materials under the latter project.

B. New and Improved Industrial Products

1. Development of Intermediates for the Production of Resins, Plastics, and Plasticizers from Pine Gum and its Components.

The preparation of chemical intermediates from naval stores products for use in industrial applications has continued. Reductive amination of ethyl pinonate with aliphatic mono- and diamines was found to proceed satisfactorily, but aromatic amines like aniline and p-phenylenediamine did not react. By this simple reductive amination process, products useful as initiators and crosslinking agents for polyurethanes and epoxy resins should be obtainable.

A study of the reactions of pinonic acid and homoterpenylmethyl ketone with acetylene to produce derivatives having potential industrial value has been completed.

Procedures were developed for the catalytic conversion of α-pinene epoxide to α-campholene aldehyde with zinc bromide, and for the preparation of α-campholenyl-α-campholenate by the Tischenko reaction from the α-campholene aldehyde. The preparation of 2,2,3-trimethyl-1-vinyl-3-cyclopentene by pyrolysis of the acetate of α-campholenyl alcohol gave poor results; methyl octyl xanthate gave good yields of octene-1. Since presumably good copolymers have been prepared in contract research at University of Arizona from ethylene propylene and the dimethyl-2, 7-octadienes from the pyrolysis of pinane, the preparation of vinyl olefins from α-campholene aldehyde and α-campholenol has more appeal since these should also copolymerize with ethylene and propylene. Research on the pyrolysis of α-campholenol will be continued. Esters of adipic, oleic and α-campholenic acids and α-campholenol will be prepared and oxidized (S5 2-38).

In another phase of work, the production of reactive chemical intermediates from turpentine by reaction with low molecular weight reagents is under investigation. Potentially useful new products have been made by photosensitized oxidation and by the reaction of dienophiles with terpenes. The major products of the photosensitized oxidation of limonene have been isolated and their physical properties determined; and progress has been made in identifying the photosensitized oxidation products of 3-menthene. Conjugated dienols and trienes obtained from limonene have unusual structures which should make them suitable as co-monomers in various types of polymers. The products from 3-menthene should include direct precursors of menthol. All available homoannular menthadienes were found to react with acrylonitrile. Further investigation of the reactions of terpenes with strong acid has revealed that the conjugated homoannular diene α-terpinene yields mixtures of gamma-terpinene, 2,4(8) menthadiene and itself similar to those obtained with other menthadienes. A combination of distillation and crystallization was used to separate the four isomers formed in the addition of acrylonitrile to α-terpinene. They were hydrogenated to saturated nitrile and amines. The two solid isomers yield the same saturated amine while the two liquid isomers yield a different one. The data obtained establishes that the two solid acrylonitrile-α-terpinene adducts are one exoendo pair while the two liquids are the other. The results to date under this project indicate that of the various reactions screened, the reaction of the terpenes with dienophiles offers the best possibilities for obtaining inexpensive useful chemical intermediates from turpentine. Emphasis of future work will be on the utilization of the primary products from the terpene - dienophile reactions, and on attempts to obtain good yields of simple addition products from the pinenes (S5 2-40).

2. Addition of Chemicals to Rosin Acids With Emphasis on Photochemical Methods to Produce Chemicals Useful in Manufacturing Surface Active Agents, Textiles, Paper and Plastics.

Studies were continued on the photochemical addition of reagents to resin acids. Palustric acid and levopimaric acid yielded dehydroabietic acid by treatment with visible light plus a molar amount of photosensitizer. Several other resin acids investigated did not react under similar conditions. The hydrogenation of levopimaric acid transannular peroxide was examined and conditions established for the selective reduction of the carbon-to-carbon double bond. Since this technique should yield a peroxide of greatly increased thermal stability, the findings will be applied to the hydrogenation of photosensitized oxidized pine gum to produce a product for testing as a vulcanizing agent for gum rubber, polyethylene, and

poly(propylene-ethylene) synthetic rubber. A scaled-up process for the preparation of photosensitized oxidized pine gum is under development. Photosensitized oxidized pine gum is a crude mixture of peroxides of known structure containing about 0.5-0.6 equivalents of peroxide per mole of resin acid persent. This product should be preparable for 10 to 15 cents per pound. A search for industrial uses for this product is underway, including its use as an intermediate in the manufacture of epoxy resins. Research will be continued on the thermal rearrangement of the acid peroxide and its ester, employing levopimaric acid transannular peroxide for the preliminary studies. (S5 2-37; S5 2-47).

3. Conversion of Turpentine and Rosin Acids into New Polymers, Protective Coatings and Resins. The resin acids of gum rosin and pine gum are monofunctional, i.e., they contain one carboxyl group. Conversion of these monofunctional substances to new polyfunction products by reaction with suitable chemicals is under investigation to develop intermediates for production of resins, plastics, plasticizers, and other industrial products.

In further research on hypochlorite modification of rosin and resin acids to produce intermediates for use in industrial resins, surface coatings, plastics, emulsifiers and similar materials, a pure, solid hydroxyabietic acid has been isolated in 30% yield from the reaction of sodium levopimarate with sodium hypochlorite. The conversion to an hydroxyabietic acid is unique. A number of useful compounds might be prepared from a reaction of this type. By understanding the reactions of hypochlorite with pure resin acids, it will be possible to apply the results to the reaction with sodium hypochlorite. The conversion to a hydroxyabietic acid is unique. A number of useful compounds might be prepared from a reaction of this type. By understanding the reactions of hypochlorite with pure resin acids, it will be possible to apply the results to the reaction with rosin. (S2 5-44).

Research has continued on the preparation of polyfunctional compounds from rosin, resin acids and resin acid derivatives by formaldehyde addition and subsequent reactions, for use in plastic formulations, resins and surface coatings. Industrial concerns have expressed interest in the methylolated rosin obtained by addition of formaldehyde to rosin, and in the glycol produced by reduction of the carboxyl group of the methylolated product. Use of neutrals-free rosin in place of rosin has been found to give more homogeneous end products. An analytical system has been developed for determination of the major components in the neutrals-free resin acid mixtures and is being applied in obtaining a better understanding of the methylolation process.

Further research on the preparation of these polyfunctional compounds through reaction with formaldehyde has shown combined dehydro- and dihydroabietic acid in neutrals-free resin acids in sufficient quantity to account for the portion of the resin acids not reacting with formaldehyde. The reaction of pure levopimaric acid with formaldehyde gave a crystalline product. The diol obtained on reduction of the carboxylic acid function is also a crystalline solid. Pure abietic acid has been reacted with formaldehyde in a closed reactor, but the products are as yet ill-defined and may be mixtures of mono- and dimethylolated materials. Although the methylolated materials obtained from pure levopimaric acid and pure abietic acid may never attain commercial importance, studies of these pure materials make possible a better understanding of the reactions involved in the methylolation of rosin or rosin derivatives. Products of the latter reactions do have much commercial promise and have stirred considerable interest in industry. The large scale methylolation of neutrals-free resin acids will be carried out, the products esterified, and the reduction to diols investigated. The structure of the methylolation products from pure resin acids will be investigated. (S5 2-43).

Further research to prepare and evaluate improved polyester resins from pine gum derivatives has led to the establishment of optimum conditions and concentrations for preparing the β-propiolactone and acrylic acid adducts of resin acids. An improved method has also been developed for separating these adducts from the modified rosin. A series of unsaturated polyesters prepared from β-propiolactone-modified rosins is undergoing evaluation by a commercial producer of polyester resins. A practical technique has been developed for the preparation of low acid number polyester resins from both fumaric- and β-propiolactone-modified rosin. The two-stage procedure avoids most of the danger of jelling the polyester and gives high molecular weight esters. Work was completed on the preparation of unsaturated polyesters from gum rosin modified at several levels with β-propiolactone; each level was condensed with the glycol ester of fumaric acid. Copolymers of these materials with styrene were evaluated and found to have commercially acceptable properties. Elliotinoic acid, the first bicyclic diterpene acid isolated from the oleoresin of the pine, was characterized. The presence of elliotinoic acid, elliotinol, and other minor constituents in American pine gum probably accounts for its unique resistance to crystallization. Evaluation of esters and polyesters of pine gum derivatives will be continued. Some of the components of rosin and modified rosin that influence the properties of polyester resins prepared from it will be isolated and characterized. Attempts will be made to develop a practical method for separating the dibasic β-propiolactone adduct in relatively pure form from the unreacted resin acids. (S5 2-42).

Progress has been made in contract research at the University of Arizona on preparation and evaluation of a number of polymers from pine gum derivatives. It has been found that vinyl pinolate will bulk polymerize, even without removal of its copper resinate stabilizer, to give conversions as high as 65% and inherent viscosities between 0.2 and 0.3. Conversions as high as 94% are obtained in emulsion polymerization. Copolymers of vinyl pinolate and vinyl chloride or vinyl acetate in benzene solution were prepared in about 45% conversion, with inherent viscosities of 0.16. Attempts to dehydrate polyvinyl pinolate by heat in order to reduce the number of hydroxyl groups led only to crosslinked insoluble products. The polymerization experiments with vinyl pinolate will be continued. Research will be initiated on the copolymerization of terpenes with olefins such as ethylene and propylene. (S4 1-89(C)).

A large concentration of rosin is undesirable in certain types of surface coating vehicles and Federal Specifications TTR 266 now specifi ally exclude rosin derivatives. If there were a satisfactory procedure for determining the rosin content, specifications could probably be modified to permit the use of small quantities of rosin in the protective coatings. Research in cooperation with the Pulp Chemicals Association has resulted in the development of a method for the determination of free rosin acids in maleic modified alkyd vehicles. Preliminary results indicate that the method can be extended to the determination of total rosin derivatives in such products. It is essential that such a method be developed if rosin is to be allowed in certain types of protective coating formulations from which it is now excluded. (S5 2-39).

C. New and Improved Processing Technology

Processing Investigations to Produce Naval Stores Products of Improved Quality at Lower Costs. In continued research to develop an improved process for isolation of pure levopimaric acid from pine gum, the yields of a 95% levopimaric acid product obtained by a three-stage 2-2mino-2-methyl-propanol process (precipitation

and two recrystallizations), using recycling, were 75% for longleaf gum (containing 38% levopimaric acid in its resin acids) and 31% for slash gum (containing 27% levopimaric acid in its resin acids). The equivalents of amine employed per equivalent of levopimaric acid for the two types of gum were 1.6 and 1.2, respectively. Although the low yield obtained from slash gum will make it desirable to use longleaf gum which has a higher initial levopimaric acid content, the process developed is simple and should be attractive commercially. Several amines other than the aminopropanol and solvent other than acetone were investigated for use in the precipitation step of the process without success. Current research has been concerned with the development of a method of analysis for the mixtures of resin acids encountered in the isolation of levopimaric acid by amine precipitation from acetone. Only levopimaric acid is readily determined at present. To ascertain the abietic type acids present use was made of gas-liquid chromatography and ultraviolet spectroscopy to determine the change in composition resulting from acid isomerization. At present, the data from gas-liquid chromatography indicate greater percentages of resin acids than the ultraviolet data. Work will continue along the same line with emphasis on developing a method which will give correlation between gas-liquid chromatography and ultraviolet spectroscopy. (S5 2-41).

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

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II. MAPLE SAP AND SIRUP - PROCESSING AND PRODUCTS
Eastern Utilization Research and Development Division

Problem. The extensive unused stands of sugar maple are largely in infertile and hilly areas of marginal value to agriculture, areas commonly devoted to small-scale dairy farming. Under proper circumstances, maple sirup could be a seasonal crop of value equal to or exceeding that of other farm products. While the results of previous research, for example, establishing the importance of sanitary collection of sap, have contributed to "modernization" of the industry, much more information is needed so that all operations for the production of high-quality maple sirup and of other maple products can be conducted in a predictable, efficient manner. Not only can the marginal farms be greatly benefited, but the existing maple industry in 14 states can be put on a higher economic plane and modernized to be made competitive with other crop and livestock farming.

USDA PROGRAM

The Department has a continuing program involving chemists, biochemists and microbiologists. These scientists are engaged in both basic and applied research in investigations concerned with the problems of improving sap handling and processing, producing high-quality maple sirup, and developing new outlets for all maple products while lessening the cost of the product. Most of this work is conducted at Wyndmoor, Pa. Contract research on factors affecting the quality of maple sirup at the Ohio Agricultural Experiment Station, Wooster, Ohio, continues.

The Federal scientific effort devoted to research in this area totals 5.5 professional man-years. Of this number 2.9 are devoted to study of the chemical composition and physical properties of maple sap and sirup, including 0.3 under the Wooster contract; 1.2 to microbiology of maple products; and 1.4 to new and improved food products and processing technology.

In the research work cooperation is maintained with personnel of the Federal Extension Service in maple-producing states and with Cornell University.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Flavor components of maple sirup. Gas liquid chromatograms indicate the presence of at least 18 components in the flavor fraction of maple sirup. Currently identified are dihydroconiferyl alcohol, syringaldehyde, and vanillin.

2. Maple sugar sand. Further analyses of samples of maple sirup and statistical evaluation of data pertaining to collection of maple sap and composition of the resulting sirup confirm previously reported correlations and provide additional information. Summarizing, there is a positive correlation between sugar sand concentration in a sirup and (a) high minimum temperature during the five months prior to sap flow, (b) a northern exposure, (c) highest elevations, (d) late stages of sap flow, (e) total organic acid content of the sap, (f) malic acid in the sap, and (g) calcium in the sap. A negative correlation was found between concentration of potassium in the sap and amount of sugar sand formed during evaporation to sirup.

B. Microbiology

1. Improved maple products through microbial fermentation. In the controlled fermentation of maple sap to modify the sap so that it produces a sirup of intensified maple flavor, or, with a "buddy" sap, so that it produces a "non-buddy" sirup, a standardized dry inoculum would provide greater control of the fermentation. Preliminary tests on the use of acetone-dried Pseudomonas geniculata cells as the inoculum are encouraging.

2. Microbiological analysis of maple sirup. In a collaborative study of a standardized procedure for microbiological analysis of maple sirup, the counts of microorganisms obtained by this procedure in fifteen government, university and industrial laboratories varied widely. The collaborative assay will be repeated.

3. Prevention of microbial growth in the taphole. An analytical method, specific for formaldehyde, was developed to determine residual formaldehyde in maple sirup so that processors could be sure that the content did not exceed the limit of 2 parts per million established by the Food and Drug Administration as stipulated in the regulations permitting use of paraformaldehyde in tapholes to prevent microbial and fungus growth.

C. New and Improved Food Products and Processing Technology

A new maple product was developed and it is being rapidly adopted by the trade. Sirup is concentrated to about 75% sugar and whipped with 1% commercial monoglycerides to give a creamy product for use as a topping, icing or spread. A particularly important feature is that the product can be prepared from all maple sirups, providing an outlet for darker sirups and those of above-average content of invert sugar.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Chemical Composition and Physical Properties

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General

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III. RANGE SEEDING, ESTABLISHMENT, AND MANAGEMENT AND VARIETY EVALUATION ON FOREST RANGES
Crops Research Division

Problem. Grazing lands of the United States occupy approximately 1,000 million acres as compared to 350 million acres of all harvested crops. It has been estimated that more than half of all the nutrients consumed by domestic livestock are provided by pastures and ranges. Improved grasslands are also essential to soil and water conservation. Information must be obtained on reliable, practical procedures for grassland management. Some of the major areas of research needing attention are concerned with seeding and establishment, including basic and applied physiological studies on the responses of pasture and range species and mixtures for different environments and management practices.

USDA PROGRAM

The Department has a continuing long-term program involving agronomists, plant physiologists, range conservationists and chemists engaged in basic and applied research on the management and improvement of grazing lands. All work is cooperative with the respective states and with the U. S. Forest Service in areas where grazing is integrated with National Forests.

The Federal scientific effort devoted to research in this area totals 2.5 professional man-years.

P.L. 480 projects in Israel relate to "Establishment and Maintenance of Seeded Dryland Range under Semiarid Conditions" and "Developmental Physiology of Perennial Pasture Grasses." Reports of another project, "Germination of the Seeds of Desert Plants," will be made available to ARS by FS.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Seeding and Establishment

1. Chemical Fallow and Furrows Effective in Cheatgrass Replacement. The intense competition which cheatgrass provides seedlings of desirable forage species can be virtually eliminated by herbicides according to studies cooperative with the Crops Protection Research Branch at Reno, Nevada. Paraquat at .7 lbs/acre in combination with a surfactant, X-77 at .1% reduced cheatgrass from 25.8 plants/sq. ft. to less than 1, and cheatgrass yields from 633 lbs/acre to 12.6 pounds. Less expensive, but somewhat less effective control of cheatgrass was provided by Atrazine, IPC and isocil, which reduced cheat to 3.2 plants/sq.ft. Perennial grasses seeded in furrows on chemically fallowed land yielded 1.8 seedlings/foot of row as compared with .9 seedling/foot on surface drilling. A 2-year old grass stand seeded on a chemical fallow yielded 824 pounds grass/acre from furrow seeding compared with 530 pounds from surface drilling. A 1-year old grass stand on chemical fallow gave the following yields and plants per foot row: 1,088 pounds and 1.6 plants for intermediate wheatgrass; 519 pounds and 1.5 plants for pubescent wheatgrass, and 364 pounds and 1.0 plant for crested wheatgrass.

2. Podosporiella Verticillata Widely Distributed in Range Soils. At Logan, Utah, and Beltsville, Maryland, studies have shown that the fungus P. verticillata could be a major factor in the failure of many range seedings. It is widely distributed in the sagebrush type in the Western States, having been identified on seeds from control studies in Utah, Nevada, Idaho, and Montana. It has also been found in the shadscale and mountain brush types. Early studies suggest that infection from the soil-borne fungus is most likely on fall planted seeds, when they have absorbed some moisture, but where moisture and temperature are not adequate to initiate rapid germination and growth. Seed treatment with Captan 75 gives good control.

B. Management

(Basic Physiology)

1. Fertility Needs of Ryegrass Determined by Leaf Analyses. At Berkeley, California, laboratory studies with Italian ryegrass have shown that nitrate accumulation in young leaves may be a reliable indicator of the nitrogen fertility status of the plant. Plants were grown in nutrient solutions with only nitrogen limited or variable, and six plant parts analyzed for NO_3 accumulation. On the basis of dry weight yield responses, under the conditions of this study the critical level of N fertilization is indicated by an NO_3 concentration of 1,000 ppm in the youngest fully open leaf. A lower concentration in this leaf indicates that the plant will respond to additional N fertilization. The method will be tested under field conditions and if effective will be extended to other nutrients and species. The study was conducted in cooperation with the Department of Soils of the University of California.

2. Moisture Stress Distorts Metabolic Processes in Subterranean Clover. Studies at Pullman, Wash., have shown that not only metabolic processes, but the phosphorylated intermediates upon which they are entirely dependent, are affected by moisture stress. Concentrations of ribulose diphosphate, phosphoglyceric acid, glucose-6-phosphate, uridine disphosphate glucose, and other phosphorylated intermediates were markedly decreased in plants whose relative turgidity was reduced to between 50 and 75%, and were decreased to less than half that of control plants when severe wilting was permitted. Inorganic phosphate was not affected. Marked recovery in most phosphorylated intermediates occurred within 24 hours after severely wilted plants were irrigated. These studies help to explain the physiological effects of moisture stress in plants and suggest a need for studies on the effect of moisture stress on phosphorylating processes and the synthesis and breakdown of enzymes which catalyze the interconversion of these intermediates.

3. Developmental Physiology Studies Progressing in Israel. In the work reported to date two phases of the problem have been initiated; (1) a study of summer dormancy in Hordeum bulbosum, an important drought resistant range grass, and (2) the development of equipment for the simultaneous and continuous determination of net photosynthesis and transpiration of intact plants. Detailed results have not yet been reported from either of these studies.

C. Variety Evaluation

(Variety Comparisons)

1. Sagebrush Continues to Invade Native Range. At Burns, Oregon, over the past 9 years, sagebrush continues to invade poor and fair condition range. On poor condition range sage increased under all levels of N fertilization, most rapidly at N levels up to 60 lbs/acre and in favorable seasons. Grasses adversely affected by N fertilization included bluebunch wheatgrass, June grass and Thurbers needlegrass. In striking contrast squirreltail increased 12-fold with N fertilization. On fair condition range perennial grasses declined from 90% to 30% of the total herbage, being replaced by cheatgrass and weeds. The change was accelerated by N fertilization. On good condition (seeded) range sage declined slightly during the 9-year period.

2. Cheatgrass Aggressive on Fertilized Range. At Pullman, Wash., cheatgrass increased and Agropyron spicatum decreased on fertilized range and the reduction in A. spicatum was accelerated by clipping at ground level during any stage of growth. On poor-condition range other grasses (primarily cheat) yielded 1/2 ton/acre on control plots and 2 tons/acre following 2 years of fertilization with 80 lbs. N/acre. Comparable figures on good-condition range were 1/4 ton and 1-1/4 tons, respectively. When mature A. spicatum was clipped at 8", the average ground cover was 7.9%. All plots clipped at ground level ranged between 3.7 and 4.8% ground cover.

3. Rapid, Objective, Method Developed for Noting Vegetation Changes. At the Central Plains Experimental Range near Fort Collins, Colorado, vegetation on blue grama range can be rapidly and objectively characterized by noting presence or absence of blue grama plants in a 2 by 2-inch quadrat and all other species in a 16 by 16-inch quadrat, of which the 2 by 2 is a part. Twenty-five quadrats on each of 10 transects were found to accurately and efficiently sample a 200 by 200-foot macroplot.

(Chemical Composition and Nutritive Value)

1. Growth Pattern of Crested Wheatgrass is Key to Management. A 6-year study at Burns, Oregon, has defined the growth pattern of crested wheatgrass on arid grazing land. Growth is slow in April, speeds up during May, and reaches a peak in early June, after which it declines, terminating in late June or early July depending on moisture. Leaves are about 6 inches long May 1, heads are in the boot in late May and emerged in early June. Anthesis is between June 25 to July 5 and seeds are hard about July 20. Dry matter percentage in the herbage increases from 28% in early May to 74% in late August, and crude protein declines during the same period from 14% to 3%. The maximum per acre yield of crude protein is reached in mid-June. Root growth is very active in April and has stopped by June 1. Carbohydrate root reserves accumulate rapidly in May, and remain relatively high thereafter. Grazed closely in mid-May, the growing point of elongating reproductive culms is removed and their further growth prevented, buds giving rise to vegetative culms are activated, and a new crop of vegetative stems develops. Thus, crested wheatgrass can be grazed throughout the spring season, until no more forage remains, or it can be grazed moderately heavily in

mid-May, to activate vegetative stem development, and rested while this new crop is produced, leading to a flexible 2-crop system of use. Both systems are compatible with the plants' pattern of growth, and accumulation of root reserves to insure sustained vigor. Under the 2-crop system, total herbage yield is about 70% of that obtained by a single complete grazing usually ending in June.

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IV. WEED AND BRUSH CONTROL ON FOREST AND RELATED RANGES
Crops Research Division

Problem. Brush infests 320 million acres of range and pasture land in the United States. Estimates indicate that brush removal can improve grazing on 240 million acres. Thus the soil, terrain and climate are adequate to support more desirable forage plants on about three-fourths of the brush infested acreage. In addition, millions of acres are infested with weed grasses and other herbaceous weeds that displace valuable forage species, reduce production and quality of forage, cause poisoning of and physical injury to livestock and reduce the quality of animal products. Also, weeds frequently cause failures in establishment of new seedings. The losses caused by weeds must be reduced by expanding research to find more effective chemical, biological, mechanical, cultural and combination methods of weed control. Expansion of fundamental studies on the physiological and biochemical responses of weeds and crops to herbicides can provide information on the relation between molecular structure of herbicides and their modes of entrance, movement, behavior, metabolism, persistence, and fate in plants and soils. Improved effectiveness of herbicides requires more information on the effects of environment, soil, plant structure, and method and time of application on plant responses.

USDA PROGRAM

The U. S. Department of Agriculture has a continuing long-term program in both basic studies and the application of known principles to the solution of weed problems. Although research is being conducted which has general application in all areas of weed control such as studies on herbicide evaluation, on the mode of action of herbicides, on fundamental principles of the role of surfactants in herbicidal effectiveness, and on the behavior and detoxification of herbicides in soils, only the research directly related to control of weeds and brush on grazing lands are included in this report. The latter includes studies of the life histories and growth patterns of individual weeds, principles of competition among weeds and forage plants and the use of cultural methods, biological agents and herbicides for their control. Comprehensive studies are made to develop principles, practices and methods of using herbicides and other weed control techniques in solving regional and national weed and brush problems in grazing lands.

Research on the control of weeds is conducted cooperatively with State Agricultural Experiment Stations and with Federal agencies, including the Bureau of Reclamation and Bureau of Land Management, Department of the Interior, Forest Service of the Department, United States Army Corps of Engineers, Department of Defense, and Plant Pest Control Division of the Department. Industrial companies cooperate in furnishing experimental chemicals, equipment, and funds essential to rapid progress in weed control investigations.

The Federal scientific effort devoted to weed and brush control research on rangelands in or near forested areas is 21.5 professional man-years.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Weed Investigations - Grazing Lands

1. Poisonous and Other Herbaceous Weeds

a. Physiological and Ecological Studies. Degradation of 4-(2,4-DB)-C^{14} by alfalfa and birdsfoot trefoil silage was demonstrated under laboratory conditions in New York. Degradation ranged from 13 to 63 percent of the material applied to forage prior to fermentation. Ensiling may be one practical method of reducing residues of some herbicides in forages.

Plants of alfalfa, birdsfoot trefoil, and ladino clover protected from rainfall and sub-irrigated in an open air greenhouse degraded 4-(2,4-DB)-C^{14}. Twenty-eight days after treatment, the amount of herbicide (C^{14}) extractable varied from 5 to 15 percent of the quantity applied. Of the forages studied, inactivation of the herbicide was least rapid in red clover. Birdsfoot trefoil degraded the herbicide most rapidly.

Preliminary investigations indicate that 4-(2,4-DB) in the dry state disappears when exposed to sunlight. Disappearance was related to the amount of radiation received. Herbicide applied to glass plates, exposed to sunlight but protected from rainfall, disappeared after 30 days.

Giant foxtail in Indiana is capable of germinating, emerging and producing seed over an entire growing season. Cutting has been shown to be a poor means of control since giant foxtail can reflower and produce viable seeds regardless of the stage when cut. Numbers of seedheads and seedhead size changed within date of seeding and within stages cut.

In Indiana, time-lapse photography has been shown to be an effective tool in the study of weed competition because it clearly shows the amount, degree and time of natural plant movement. By indicating times of maximal elongation, the arrangement and positioning of leaves, the complexity of light competition can truly be appreciated especially in terms of measuring the environment.

Data taken during six seasons in Nebraska indicates greatest dormancy of buds of ironweed is during the months of August, September, October, and November. Ironweed apparently has no dormancy during the months of March, April, and May. Approximately 60 percent of the buds harvested during the dormant period do not sprout when provided optimum conditions for sprouting. These may be used for studies requiring buds known to be dormant.

Dormancy of buds in ironweed evidently consists of recurring annual cycles of no dormancy followed by absolute dormancy. During the "no dormancy" or "active" stage, buds behave similarly (e.g., none are dormant). Since all buds are active during one part of each year, long-term dormancies such as exist in the buds of certain other species is not present in ironweed. When ironweed stands are clipped during the summer months the response of the axillary bud is related to the height of clipping. When dormancy is only partially extablished, sprouting activity of buds is greater when the stem is cut low than when the

stem is cut high. As dormancy becomes more firmly established the length of stem which is allowed to remain is of less importance.

Sprouting of hardshell bulbs of wild garlic from Kentucky and Missouri were nearly identical (30%) during a season in Missouri. Eighty-five percent sprouting occurred with excised primordia from dormant hardshell bulbs of wild garlic indicating that primordia have the potential to sprout but may be blocked by a physical and/or chemical mechanism in the surrounding tissue. Concentrated extracts of hardshell garlic bulbs decreased growth of plant material in bio-assays indicating the presence of an inhibitor material and/or materials.

Leaf samples of tall larkspur, (Delphinium barbeyi) collected 1, 2 and 3 weeks after spraying with an amine salt of 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) and 2-(2,4,5-trichlorophenoxy) propionic acid (silvex) had much higher concentrations of alkaloids than those of untreated plants in Utah. Plants treated with silvex contained more alkaloids than those treated with 2,4,5-T. Both chemicals have effectively controlled tall larkspur if applied in the late vegetative to very early bud stage of growth.

Snakeweed (Gutierrezia microcephala) has a root system which has a lateral spread which is about four times that of the aerial portions in Arizona. The roots are most common in the surface 6 inches of soil. Dormant buds occur in a band above and below the root crown. These buds grow in the early spring. Older plants dominate the site, causing a stagnate stand; this may account for the sudden disappearance of this short-lived perennial weed without management or control efforts. Control of this weed would mainly shorten the period in which the grasses are suppressed. Also, lack of germination of locoweed, (Astragalus lentiginosus) seeds collected in 1961 may explain the present absence of this weed in areas in which it had formerly been abundant.

Analysis of the data from sampling weed species in Nebraska and construction of frequency distributions from these series of successive samples showed that, (1) stems or plants of weeds per unit area are seldom arranged in a random manner but rather in an aggregated or clumped pattern, (2) using a small sample area on species having such a pattern results in a skewed frequency distribution closely resembling the contagious types of theoretical distributions. These distributions can be made to approach normality by increasing the sample area. An alternate method of normalizing such a distribution is to adjust sample size to a certain range then apply a log or log (N+1) transformation.

b. Weed Control Studies. For the second year, atrazine at 1 lb/A proved to be the best control for medusahead and also for downy brome in Washington. Best stands of crested wheatgrass (Agropyron desertorum) seeded one year after application of herbicides were also on plots treated with atrazine. Fall application of this herbicide on winter annual grasses was more reliable than spring application.

1,1'-dimethyl-4,4'-bypyridinium salt (paraquat) from 2.8 to 0.7 lb/A cation, when applied at time of spring seeding gave excellent post-emergence downy brome control and was not injurious to seedlings of pubescent wheatgrass in Nevada. Effectiveness of paraquat in downy brome control at rates of 0.36 lb/A

cation and lower was generally increased by late afternoon application as compared with morning application. Paraquat was not effective in downy brome control even at 0.7 lb/A cation without an effective surfactant.

Three chemicals, 2-methoxy-4-ethylamino-6-isopropylamino-s-triazine (atratone), ametryne, and prometone, prevented all seed production of halogeton for two years (1961 and 1962) without serious injury to perennial kochia (Kochia americana) in Utah.

Spraying with silvex or 2,4,5-T at rates of 2 lb/A reduced timberline milk vetch (Astragalus miser var. decumbens) by 99 to 100% during the first year following treatment in Utah. Surviving plants and newly established plants account for less than 1% of the pre-treatment population three years after treatment.

The most promising herbicide of 15 evaluated on bracken fern in 1962 was dicamba at 8 lb/A in Washington. Also, dicamba has shown selective control of wild garlic in established forage grasses in Indiana and warrants further investigation.

Good to excellent control of most weeds occurring in native grasses in Oklahoma have been obtained with 2,4-D ester at .75 pounds acid per acre applied in May or June. Plants not controlled were ironweed, buckbrush, sumac and skunk brush. One pound of 2,4-D ester per acre in a single or repeated application had very little effect on native legumes such as native lespedeza, yellow neptune, prairie clover, lead plant, wild alfalfa and sensitive briar.

Preemergence treatments with an ester formulation of 2,4-D applied at rates of 1 and 3 lb/A acid during the latter part of March and April gave satisfactory control of western ragweeds, annual broom weeds, yarrow and most all annual broadleaved weeds commonly found in native grass pastures in Oklahoma. The 2,4-D had no residual effect on weeds beyond the year applied.

The satisfactory control of weeds in Indiana in the establishment of forage legumes requires combinations of materials presently available. The choice, rates, and timing of application will depend on weed species, densities and seasonal variation in weather. The use of wetting agents to increase the effectiveness of lower rates of some herbicides appears to be both practical and economical.

EPTC and R-1607 were the only herbicides that gave satisfactory legume establishment in the main legume establishment plots in 1962 in New York. The combination of 4-(2,4-DB) + dalapon was successful in one experiment but not in another. The thiocarbamate herbicides were particularly effective on nutgrass. In Missouri, preemergence applications of diphenamid at 2 and 4 and DCPA at 4,6, and 8 lb/A controlled weed grasses in seedling alfalfa, but failed to control broadleaved weeds. Diphenamid preemergence and 1 lb/A of 4-(2,4,-DB) postemergence controlled all weed species without injury to alfalfa.

2. Brush Control

a. Physiological and Ecological Studies. Research at Tempe, Arizona shows the visible leaf injury resulting from treatments of 3-phenyl-1,1-dimethylurea (fenuron) on shrub live oak seedlings is not due directly to the depletion of

energy supply resulting from inhibited photosynthesis. An alternative hypothesis is proposed, i.e., visible leaf injury is caused by a toxic accumulation product of a fenuron-blocked reaction in the photosynthetic mechanism. A second type of inhibition occurs at high fenuron concentrations and is evident in the inhibition of root growth independent of the photosynthetic inhibition and its toxic accumulation product. Also, only slight difference was found in the development of injury symptoms of leaves of shrub live oak seedlings in low and high humidities. One explanation for this is that upward movement of fenuron is not entirely dependent on transpiration.

Because of evidence that a thick leaf cuticle is one of the primary factors limiting absorption of foliar-applied herbicides, a microscopic study was made of relative cuticle development in outdoor mesquite trees and simultaneously in greenhouse-grown and outdoor-grown seedlings at Tucson, Arizona. Although trees develop a cuticle of 5 microns or more in thickness by the third month following bud-break in March, both greenhouse- and outdoor-grown seedlings of the same age form cuticles which are barely visible under the microscope and only a micron or less in thickness. The study indicates that cuticle development is more a function of plant size or age, rather than whether or not it is grown in a greenhouse or outdoors.

Soluble reducing sugars in the older root tissues of camel's thorn (Alhagi camelorum) fluctuated somewhat in response to the various 2,4-D spraying regimes in different growth stages, but there was no readily apparent relationship between 2,4-D spraying regimes and percent content of reducing sugars in the older roots of treated plants in Washington. Percent reserve carbohydrates in the older roots did not vary from untreated plant values regardless of the 2,4-D spraying regime used.

Seed of camel's thorn did not germinate readily without scarification of the seed coat. The optimum germination temperature of scarified seed was near 25° C. About 60 percent of unscarified seed survived 96 hours of stay in the rumen of a fistulated Hereford steer on roughage ration. On a high concentrate ration 80 percent survived 144 hours of stay. Cattle spread camel's thorn.

Soil from near juniper roots inhibit grass growth, but some individual grass plants of each species tested were not effected by junipers at all in Arizona.

b. Control Studies. Also, in Arizona repeated biannual applications of 2 lb/A of an ester of 2,4,5-T over a three-year period killed over 90 percent of treated shrub live oak plants but repeated annual applications of 2 lb/A of 2,4,5-T over a three-year period did not kill an appreciable percentage of the treated bushes.

Pelleted fenuron at 8 lb/A killed over 80 percent of shrub live oak bushes; at 16 lb/A control exceeded 90 percent. These figures are probably conservative since surviving bushes were at the margins of plots. Lehmann lovegrass re-established itself 12 - 16 months after treatment with 16 lb/A of fenuron.

Preliminary evaluations indicate that dicamba may be more effective as a foliar spray for control of shrub live oak than any of the other herbicides tested to date.

Weight of shrub live oak sprouts after May and June of 1960 top removal was three times as great in August 1962 as when tops were removed in September and October 1960.

Only a few post and blackjack oak sprouts are appearing on areas in Oklahoma having repeated annual aerial spraying of 2,4,5-T eight to ten years ago which caused 70 to 80 percent kill of small brush and trees.

In Oklahoma, surfactants Tergitol, NPX, Triton X-114 and Emcol H-86C each used in emulsions of the butoxy ethanol ester of 2,4,5-T foliar applied at 2 pounds acid in 5-gallons of water per acre for 2 years caused apparent kill and defoliation of post and blackjack oaks that was equal or slightly greater than that from 2,4,5-T ester in a commercial formulation produced for aerial spraying. Each of three surfactants made up 1% of total spray applied.

Dormant stem spray applications of 2,4,5-T shows promise for controlling sprouts of Gambel oak (Quercus gambelii) in Arizona. By the end of the first growing season following treatment there was an apparent root kill of 50 percent and a stem kill of 92 percent.

Granulated 2,3,6-TBA applied to the soil at the base of alligator, one-seed, and Utah junipers was as good as or better than pelleted fenuron applied at the same rates.

Eight and 16 pound rates of 2,3,6-TBA per acre applied in either the summer or fall controlled camel's thorn in Washington without appreciable reduction in perennial Distichlis stricta and annual Bromus tectorum populations which were of some value for grazing use.

An ester of 2,4-D was slightly more selective for big sagebrush than 2,4,5-T ester. Two lb/A is recommended for the selective control of big sagebrush in bitterbrush stands in Oregon. Delaying spraying progressively from the time of leaf appearance until early fruit development of bitterbrush resulted in greater 2,4-D damage. Spraying at any time killed virtually all leaf tissue and current twig growth of bitterbrush; however, spraying at the time of leaf origin and before the appearance of distinct twig elongation or flowers left only a small amount of dead tissue on large plants. Subsequently, dormant buds initiated new growth and in the autumn only slight evidence of spray injury remained. The amount of growth attained from dormant buds depended upon the duration of favorable growing conditions after spraying. In contrast to large bitterbrush, those less than 12 inches tall were consistently killed.

Comparisons of repeated mowing and spraying treatments for 2 years on buckbrush in late May in Nebraska showed that while mowing gave the appearance of partial control because the old woody stems were knocked down and only recent sprouts or new stems were standing. However, mowing only reduced the stand 24 percent. Spraying with 2,4-D at 1 and 2 lb/A reduced the stand 90 and 92 percent respectively. Spraying with a mixture of 2,4-D and 2,4,5-T at the same rates gave 80 and 86 percent control.

Short leaf pine in Oklahoma that were defoliated or had terminal injury from 2,4,5-T aerial applications recovered the year after being treated and made normal foliage and height growth. Where cone injury occurred following 2,4,5-T applications the seed trees set and produced normal cones the year following the herbicide treatment.

Injector treatments with undiluted triethy amine of 2,4,5-T (4 lb acid per gallon) killed 99 to 100 percent of winged-elm brush and trees in Oklahoma. Control of oak with the same treatment was good, but hickory and ash were resistant to initial treatment and required retreating to obtain satisfactory control.

Defoliation of post and blackjack oaks in Oklahoma with low volatile ester of 2,4,5-T at 1-1/4, 2-1/2, and 3-3/4 lb/A each in 20 gallons of diesel oil per acre were moderately successful. Treatments were applied September 18 to 20, 1962 and defoliated 85, 86 and 96 percent respectively for the rates used. Dinitro and pentachlorophenol at 3, 6, and 9 pints in the same volume of diesel oil was only about 1/3 as effective in defoliation of oaks as 2,4,5-T. Sodium metaborate at 12, 16, and 20 pints each in 20 gallons of water per acre was about equal to dinitro and pentachlorophenol in defoliation of post and blackjack oak. Seven-oxabicyclo-(2.2.1) heptane-2,3-dicarboxylic acid (endothall) at the same rates as sodium metaborate was only about 1/3 as effective as the latter.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Weed Investigations - Grazing Lands

Poisonous and Other Herbaceous Weeds

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